Abstract—Recently, nanomaterials are developed in the form of nano-films, nano-crystals and nano-pores. Lanthanide phosphates as a material find extensive application as laser, ceramic, sensor, phosphor, and also in optoelectronics, medical and biological labels, solar cells and light sources. Among the different kinds of rare-earth orthophosphates, yttrium orthophosphate has been shown to be an efficient host lattice for rare earth activator ions, which have become a research focus because of their important role in the field of light display systems, lasers, and optoelectronic devices. It is in this context that the $4f^{n} \leftrightarrow 4f^{n-1} 5d$ transitions of rare earth in insulating materials, lying in the UV and VUV, are the aim of large number of studies. Though there has been a few reports on Eu$^{3+}$, Nd$^{3+}$, Pr$^{3+}$, Er$^{3+}$, Ce$^{3+}$, Tm$^{3+}$ doped YPO$_4$. The $4f^{n} \leftrightarrow 4f^{n-1} 5d$ transitions of the rare earth dependent to the host-matrix, several matrices ions were used to study these transitions, in this work we are suggesting to study on a very specific class of inorganic material that are orthophosphate doped with rare earth ions. This study focused on the effect of Ce$^{3+}$ concentration on the structural and optical properties of Ce$^{3+}$ doped YPO$_4$ yttrium orthophosphate with powder form prepared by the Sol Gel method.

Keywords—YPO$_4$:Ce$^{3+}$, 4fn$\leftrightarrow$ 4fn-1 5d transitions, scintillator.

I. INTRODUCTION

Recent reports demonstrate that the doped rare earth ions RE$^{3+}$ could be the promising scintillator materials [1],[2]. Rare earth doped orthophosphates (LnPO$_4$: Ln=La, Ce, Gd or Y) have been attracting much attention [3]. Due to the high energy band gap, high thermal and chemical stability, high luminescence quantum yield, and sharp emission bands of orthophosphate host.

Lanthanide phosphates LnPO$_4$ crystallize in two polymorphs, that is, tetragonal phase with xenotime structure and monoclinic phase with monazite structure.

Yttrium orthophosphate YPO$_4$ crystallizes with the zircon structure (xenotime type) with a tetragonal symmetry ($a=b=0.6894$nm and $c=0.6027$nm) and space group I$4_{1}$/amd [4]. Where the site symmetry for Y$^{3+}$ ions is D$_{2d}$ point-group [6]. The structure can be described as chains parallel to the c axis of corner-sharing structural units built of (YO$_6$) dodecahedron and a (PO$_4$) tetrahedron linked together by an edge [5], [6] (Fig. 1).

II. SAMPLES PREPARATION

For preparation of nanophosphors samples with powder form used in the present work we have adopted the sol gel method, four samples of Ce$^{3+}$ doped YPO$_4$ prepared with different concentration of Ce:Y$_{1-x}$Ce$_x$PO$_4$ ($x=0.5\%$, $1\%$, $2\%$, $5\%$).

In a typical synthesis process, appropriate amount of Y$_2$O$_3$ (99.99%), (NH$_4$)$_2$HPO$_4$ (>99.0%), Ce (NO$_3$)$_3$.6H$_2$O dissolved in appropriate amount of solution (Deionized water + nitric acid) the final mixture obtained stirred for 10h after that a...
certain amount of organic additive (ethylene glycol EG) added and stirred for 2h, then the pH of solution was adjusted to 2 by addition of NH₃·H₂O solution, finally, the colloidal solution was obtained.

The resulting solution dried at 100°C for obtained the samples Ce³⁺ doped YPO₄ samples with powder form.

III. STRUCTURAL CHARACTERIZATION

A. XRD Analysis

All the powder of YPO₄: Ce³⁺ nanophosphors annealed at 900°C for 4h with step of 2°/min.

The structure of the resulting powder was characterized by X-ray Powder diffraction (X'Pert SW) with CuKα radiation, λ=0.154056nm employing a scanning step of 2°/min in the 2Theta from 10° to 100° range.

The XRD Patterns of YPO₄:Ce³⁺ samples prepared with different concentration of Ce³⁺ shows well crystallized tetragonal phase (Xenotime structure) according to JCPDS 09-0377 Fig. 2.

![Fig. 2 XRD patterns of YPO₄:Ce³⁺ powder annealed at 900°C for 12h](image)

The unit cell volume and lattice parameters of all prepared samples are calculated and summarized in Table I.

<table>
<thead>
<tr>
<th>Concentration (Ce%)</th>
<th>a (Å)</th>
<th>b (Å)</th>
<th>c (Å)</th>
<th>Cell volume (Å³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>6.876</td>
<td>6.876</td>
<td>6.010</td>
<td>284.14</td>
</tr>
<tr>
<td>1</td>
<td>6.873</td>
<td>6.873</td>
<td>6.02</td>
<td>284.37</td>
</tr>
<tr>
<td>4</td>
<td>6.884</td>
<td>6.884</td>
<td>6.024</td>
<td>285.47</td>
</tr>
</tbody>
</table>

The unit cell volume of the samples increases with increasing concentration of Ce³⁺ in YPO₄, because the ionic radius of Y³⁺ (0.9 Å) [9] is less than Ce³⁺ (1.14 Å) [8]. The increase in the unit cell volume with increasing concentration of Ce³⁺ indicates the quantitative substitution of Ce³⁺ in the lattice site of Y³⁺ in YPO₄ matrix.

B. Grain Size

After that confirmed the pure phase of the powders YPO₄:Ce³⁺ prepared with sol gel process we have calculated the grain size of this powders.

The average crystallite size (D) was calculated from Scherrer relation [10]:

\[ D = \frac{0.89 \lambda}{\beta \cos \theta} \] (1)

where D is the effective particle size, β is FWHM, θ is the diffraction angle, λ is the X-ray wavelength, the coefficient 0.89 is used to correct the particle size.

Fig. 3 shows the variation of grain size with Ce concentration.

![Fig. 3 Grain size of YPO₄: Ce³⁺ nanophosphors calculated from Scherrer formula for (200) plan](image)

IV. PHOTOLUMINESCENCE STUDY

The interconfigurational 4f-4f5d spectroscopy of the nanopowder YPO₄:Ce³⁺ was measured using Perkin Elmer LS 50B luminescence spectrometer equipped with a 150 W Xenon lamp in the range of 200nm-800nm.

A. Ce³⁺ Ion Spectroscopy in YPO₄ Matrix

Fig. 4 shows the 4f and 5d levels of Ce³⁺ ion in the YPO₄ host [11].
It’s very clearly that the YPO4 hosts appropriate to get the good efficient luminescence for Ce3+ ion doped YPO4 because it provides the very large space for 4f and 4d levels of Ce3+.

B. Emission Spectra of YPO4:Ce3+ Nanophosphors

The emission spectra of the samples under excitation λ_{ex}=245nm are shown in Fig. 5.

![Emission spectra of YPO4:Ce3+ nanophosphors](image1)

All spectra emission of nanophoturber are studied in the spectra range of 260nm-450nm. The emission spectrum taken at an excitation wave length of 245 nm shows two emission bands centered at 330nm and 355nm, One relatively weak band peaked at 330 nm may be ascribed to the transitions from the excited state levels, which is the lowest crystal-field component of the 5d1 configuration to the ground state levels 5\text{F}_{4,5} of the 4f1 configuration of dopant Ce3+ [12], other band attributed to the 5d1-\text{F}_{7/2} transition.

The intensity of each band increase with increasing of the concentration of Ce3+ in the YPO4 host between 0.5% and 1% after that the intensity of bands decrease with increasing of the concentration of Ce3+. Fig. 6 shows the variation of luminescence intensity of 5d1-\text{F}_{7/2} transition with Ce3+ concentration.

![Emission spectra at room temperature of the YPO4:Ce3+ samples studied under λ_{ex}=245nm](image2)

The results of luminescence quenching in Fig. 6 show that, for the YPO4:Ce3+ nanophoturber, the optimum dopant concentrations of Ce3+ ions is 1%.

C. Chromaticity Coordinates

For understand the luminescence color of the Ce3+ doped YPO4 samples after excitation (λ_{ex}=245nm) we have calculated the chromaticity coordinates.

Table II shows the chromaticity coordinates (x, y) of YPO4:Ce3+ nanophosphors and respective color from CIE diagram.

<table>
<thead>
<tr>
<th>Concentration (Ce%)</th>
<th>x</th>
<th>y</th>
<th>CIE Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>0.16309</td>
<td>0.01219</td>
<td>Blue</td>
</tr>
<tr>
<td>1</td>
<td>0.163</td>
<td>0.01230</td>
<td>Blue</td>
</tr>
<tr>
<td>2</td>
<td>0.1629</td>
<td>0.0123</td>
<td>Blue</td>
</tr>
<tr>
<td>4</td>
<td>0.1629</td>
<td>0.0123</td>
<td>Blue</td>
</tr>
</tbody>
</table>

V. Conclusion

- YPO4: Ce3+ nanophosphors are successfully synthesized through sol-gel method at moderate temperature (900 °C)
- The prepared YPO4: Ce3+ crystallizes in a single-phase, Tetragonal structure.
- In this study the influence of Ce3+ concentration doped YPO4 host on their structural and optical proprieties is confirmed, So, we have given the emission spectra of Ce3+ doped YPO4 with difference concentration (0.5%, 1%, 2%, 4%) under excitation λ_{ex}=245nm.
- Finally, the mechanism of luminescence quenching in the YPO4:Ce3+ is studied; the optimum dopant concentration is 1%.

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REFERENCES